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SOME EFFECTS OF TEMPERATURE, RELATIVE HUMIDITY, CONFINEMENT, AND TYPE OF FOOD ON QUEEN BEES IN MAILING CAGES[1]

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Introduction

The extensive development of the queen-rearing industry in the United States[2] has been accompanied by serious problems relating to the transportation and handling of queen bees. Each year, particularly during the warmer season, many queens die in the mails while en route from the breeder to the purchaser. Further losses take place before the queens can be introduced to their new colonies. Often the beekeeper cannot use the queens immediately after he receives them, but he is seldom able to hold them successfully more than a few days unless special provision is made for their safety. Some beekeepers place a number of the caged queens within a queenless colony for storage. More frequently they are kept in a cool, dark place until they can be used. While the shipper usually replaces queens lost in shipment, replacements increase the cost of producing queens, and the incidental delay in effective delivery at times may result in serious losses to the purchaser. The purchaser also may suffer losses in colony production if the queens have been so injured by shipping conditions as to impair later performance.

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[1] A contribution from the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, in cooperation with the University of Wyoming.

[2] The Annual Reports on the Volume of Business, published by the Office of the Managing Director of the Marketing Agreement for Shippers of Package Bees and Queens, Auburn, Ala., show that a yearly average of nearly 200,000 queens were marketed during the 3-year period 1935-37. Nearly half of these were sold with package bees and/or nuclei. The remaining queens, a yearly average of 101,011, were marketed separately, presumably in mailing cages. And 52.96 percent of those marketed in mailing cages were sold during the warmer months of June, July, and August.

The transportation of queen bees was extremely hazardous during the early days of the beekeeping industry in the United States. Later, as the traffic in queens bred in this country developed, they were shipped more successfully as a result of the improvements in food, the carrying of queens by mail, and the improvements in transportation and communication which reduced the time required for delivery.

When A. I. Root (6)[3] was confronted with the problem of holding a large number of queens which had been banned from the mails, in 1878, he discovered that, by supplying water as well as the usual food, queens could be held in cages for comparatively long periods. This led to the use of small water bottles in the shipping cages, and queens were shipped with fair success for long distances. At that time the foods used consisted of honey, sometimes contained in a small sponge; candy made of honey, flour, and sugar; or candy made of "coffee A" sugar.

According to an editorial in Gleanings in Bee Culture in 1913 (1), this early use of water in the mailing cages was discontinued after a few years, following the introduction of the so-called "Good" candy.[4] The editor believed, however, that the "Good" candy did not entirely relieve the need for water. He stated: "When no water is supplied it is imperative that the candy be soft and moist. If too moist it will dissolve and daub the bees; if too dry they will starve within a few hours. * * * If we can arrange to give the bees water while en route by mail, the softness or hardness of the candy would be of no material consequence. Indeed, we now believe we can use a dry hard candy." This revival of the use of water for the shipment of queens also was soon dropped, apparently because of the inconvenience and the difficulty in finding suitable containers for water.

An editorial in the American Bee Journal in 1921 (2) recommended that queens, after being received through the mails, be placed in a dark, quiet place of even temperature, and that they be given water when the candy becomes hard, not because the bees need water, but because the water is needed to soften the candy. A later editorial in the same publication (3) stated that in the shipment of bees without brood no water is needed if the food is not too hard to be consumed, and that water, in that it loads their stomachs unnecessarily, is injurious.

Several methods were used to supply water to queens in mailing cages. A. I. Root (6) first used 1-dram vials with a groove cut in one side of the cork to allow the bees access to the water. Several other devices were used

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[3] Numbers in parentheses refer to Literature Cited, at the end of this circular.

[4] The "Good" candy, made by kneading sufficient powdered sugar into honey to make a stiff dough, first was suggested for use in shipping bees and queens in this country by I. R. Good (5) of Indiana. In Europe it was known as the "Scholz" candy, being first made by a German named Scholz many years before, for use in feeding bees in colonies.

or suggested, but all were in some way unsatisfactory, since they were not dependable, and considerable extra labor was required to fit them to the mailing cages. In some cases leakage occurred so as to wet the food and daub the bees. These factors probably were the most important in causing the use of water to be discontinued at various times.

Although a large proportion of the queens provided with "Good" candy survive when sent through the mails, it is desirable to reduce the losses that occur. Furthermore, it is desirable to improve methods for holding queens and to reduce the possibilities of injury resulting from confinement in mailing cages. The apparent benefits resulting from the early use of water for queens in mailing cages raise the question as to whether candy alone is satisfactory, or whether water also should be supplied.

To obtain information on the effects of temperature and relative humidity, as well as the influence of water and other foods, on queens in mailing cages, experiments were conducted by the Division of Bee Culture during 1936, 1937, and 1938. The investigations were begun in 1936 by C. E. Burnside of the Bee Culture Laboratory at Beltsville, Md., who made observations on a large number of mailing cages containing only worker bees, which were subjected to a variety of environmental conditions and provided with various foods. The work was continued by the writer during 1937 and 1938 at the Intermountain States Bee Culture Field Laboratory at Laramie, Wyo., using worker bees and queens with and without attendants.

Experiments with Worker Bees

In experiments conducted by Dr. Burnside of the Beltsville, Md., laboratory, queen-cage candies prepared according to different formulas were compared. There was no evidence that one kind of queen-cage candy was better than another when fed to worker bees. When water in small feeders was available to the bees, however, bees feeding on candy in some cases lived as much as eight times as long as bees receiving only candy. At room temperatures (about 70° to 75° F.) bees lived approximately the same length of time on candy without water as with water when the relative humidity was nearly 100 percent, but their life was short and the damp conditions were favorable for the growth of fungi. Under all other conditions investigated the length of life was materially increased when water was supplied. With a temperature of 98.6° F. the length of life was from 2 to 7 days without water, and from 31 to 50 days with water; with temperatures of 68° to 75° the length of life was from 4 to 17 days without water, and from 11 to 33 days with water. At both the higher and lower temperatures the length of life was greatly increased when water was provided. Lump or domino sugar appeared to be as good a food for bees in queen cages as did candy when water was available. Experiments in which pollen or pollen and starch were added to candy showed that these materials had little effect on worker bees, as they neither increased nor decreased the length of life, except that with just-emerged bees the addition of pollen increased the length of life from as much as about 25 percent to over 100 percent.

Experiments conducted by the writer at Laramie, Wyo., showed that a more dilute food than queen-cage candy was necessary for maximum longevity of worker bees in cages. They lived a comparatively long time on syrup alone, made of half cane sugar and half water, at temperatures of about 85° F., but with more concentrated foods, or at higher temperatures, additional water was necessary. In these experiments bees lived longer even on honey when water was available. Under comparatively dry conditions, water was beneficial to caged worker bees feeding on most of the more concentrated foods; under moist conditions the need for water was lessened. When bees had access to water in a separate container, they were able to make the necessary water adjustment.

Experiments with Queen Bees

The experiments with queen bees consisted of confining queens in standard six-hole mailing cages and exposing them to various conditions of temperature and relative humidity. The foods supplied were queen candy,[5] pollen candy, sugar syrup, and water. The pollen candy was prepared by adding pollen collected by bees to the queen candy so that the pollen comprised 4 percent of the mixture. The sugar syrup was made of cane sugar and water. Water was supplied certain queens in two types of feeders. One feeder consisted of a specimen vial (fig. 1) with a flat-topped aluminum screw cap containing three holes about 1/32 inch in diameter. This feeder, filled with water, was inverted over the screen of the mailing cage. The other feeder used was a small vial fitted into each mailing cage horizontally through a hole in one end. It contained about 4 cc. of water held in place by a cotton plug or cork stopper. Sometimes a cord wick was used to carry water to the opening. The inverted screw-capped vial feeder described first was the more satisfactory, as the bees always were able to obtain water, while the second type of feeder sometimes failed to function, or the water supply was insufficient.

For experiments under conditions of controlled temperature and relative humidity, the caged queens were placed in cabinets previously described (7). The temperature was electrically controlled, and the relative humidity was controlled by the use of saturated salt solutions. The procedure in most experiments consisted of keeping the caged queens within the cabinets for various periods, after which those surviving were introduced to established colonies or to package bees. The queens were released among the bees when they were introduced, instead of cage methods of introduction being used, so that they might begin to lay as soon as they were capable of doing so. The spray and direct-release procedure described by Farrar (4) was followed for queens introduced to package bees. Queens introduced to

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[5] The candy used in all the following experiments conducted at Laramie was freshly prepared by kneading commercial powdered sugar (6X containing 3 percent of starch to prevent caking) into heavy-bodied, water-white, sweetclover-alfalfa honey until the proper consistency was obtained.

established colonies were released on the combs after the bees of the colonies had been sprayed with sugar syrup in much the same way. The recorded time of initial egg laying was based on the age of the unsealed brood observed, and also on the time of emergence of the first progeny of the new queen. The tendency toward supersedure was observed in some of the colonies. Supersedure was assumed in all cases where queen cells containing developing brood were found, although in some colonies no more cells were built after those first found were destroyed.

The queens used were obtained at several different times and were from several sources. Most of them were young queens received through the mails from the South, but some were older laying queens removed from the laboratory's experimental colonies. They were not all equally good in quality, but the uniformity of the results obtained in the experiments indicates that the variations in the queens had little effect on the results. While the experiments were not all performed at the same time, the close agreement of the results allows the grouping of them into a limited number of summaries.

Influence of Temperature, Relative Humidity, Type of Food, and Confinement on Survival of Queens and their Ability to Lay Eggs

Table 1 shows the effect of a number of conditions of confinement on the ability of 75 queens to survive in mailing cages, and on their ability to begin to lay eggs after introduction to established colonies or package bees. The presence or absence of water as part of the food was more important than the type of candy, the period of confinement, or temperature and relative humidity. Only 3 of the 30 queens fed candy or pollen candy without water lived more than 5 days in confinement, whereas all but 3 of the 45 queens which received water in addition under the same environmental conditions survived confinement ranging from 7 to 17 days. All the queens receiving water lived more than 5 days, and 93 percent of those held 2 weeks or more survived. Those failing to survive when water was supplied lived an average of 10 days, as compared with only 3.9 days for those without water.

Temperature differences within the range of 85° to 99.5° F. had no apparent effect on the survival of the queens provided with water, but the lower temperatures were more favorable for those without water. The greatest length of life without water at 99.5° was 2 days, while at 85° one queen lived 10 days.

Table 1.--Influence of temperature, relative humidity, type of food, and length of confinement of queens in mailing cages on survival in confinement and time of initial egg laying after introduction to colonies

Confinement conditions		Number of queens confined	Length of confinement period, days	Food	Queens not surviving confinement		Queens surviving confinement	
Temperature, °F.	Relative humidity, percent				Number	Avg. length of life, days	Number	Time of initial egg laying after introduction, days
85-86	24-27	4	14	Candy	4	4	0	--
		6	14	Candy and water	1	9	5	1-5
		4	14	Pollen candy and water	0	--	4	1/2-3
	51	4	14	Candy	4	7	0	--
		4	14	Candy and water	0	--	4	1/2-5
92.5	20-25	1	7	Candy	1	3	0	--
		1	7	Candy and water	0	--	1	2
		6	14	Candy	6	3	0	--
		6	14	Candy and water	0	--	6	1/2-2
		6	14	Pollen candy and water	1	12	5	0-3 1/2
		1	17	Candy	1	3	0	--
		1	17	Pollen candy	1	3	0	--
		1	17	Candy and water	0	--	1	5
		1	17	Pollen candy and water	0	--	1	1
	50	6	14	Candy	6	4	0	--
		6	14	Candy and water	1	9	5	0-3
		1	17	Candy	1	3	0	--
		1	17	Pollen candy	1	3	0	--
		1	17	Candy and water	0	--	1	3
		1	17	Pollen candy and water	0	--	1	2
	66	1	7	Candy	1	5	0	--
		1	7	Candy and water	0	--	1	2
99.5	19	2	14	Candy	2	2	0	--
		3	14	Candy and water	0	--	3	1-3
		2	14	Foller candy and water	0	--	2	2-3
	45	2	14	Candy	2	3	0	--
		2	14	Candy and water	0	--	2	2

The queens not provided with water died more quickly under the lower relative humidity conditions, the average length of life being 3.2 days at 19 to 27 percent relative humidity, and 4.7 days at 45 to 66 percent relative humidity. Differences in relative humidity within these ranges had no apparent effect on the survival of queens provided with water. The best survival without water occurred at 85° F., relative humidity 51 percent.

The presence of pollen in the candy had no effect on the queens when water was provided. Both the queen candy and the pollen candy became quite hard in most cages before the end of 2 weeks in the cabinets, particularly at the higher temperatures and lower relative humidities. The pollen candy hardened more quickly and completely than the pure candy, but the hardness of the candy had no detrimental effect when water was available. The queens which received no water always died before the candy became hard. This seems to demonstrate that the queens needed water for metabolic processes, rather than to soften the candy because it was too hard to be fed upon. The necessity for water was increased as the temperature was increased and as the relative humidity was decreased.

None of the queens surviving confinement seemed to be injured, as they all began to lay eggs in 5 days or less. Some apparently began to lay almost immediately after being released in colonies. The time of initial egg laying was not affected by variations in temperature between 85° and 99.5° F. Neither did the relative humidity variations (19 to 66 percent) nor the addition of pollen to the candy have a noticeable effect. A comparison of the time required for initial egg laying of 36 queens installed with package bees after being confined 2 weeks with that of queens confined from 3 to 6 days, and of queens installed on arrival from the South, is given in table 2. While the differences shown in the table probably are not important and are influenced by individual queen variations, they demonstrate that the confinement for 2 weeks or less was not detrimental to the initiation of egg laying.

Table 2.--Comparison of time required, after installation with package bees, for initial egg laying of queens confined 2 weeks, queens confined 3 to 6 days, and queens installed on arrival from the South

Treatment	Number of queens	Average number of days to begin laying
Queens confined 2 weeks and then installed with package bees	36	1.6
Queens confined 3 to 6 days and then installed with package bees	32	2.5
Queens installed with package bees on arrival from the South	30	2.1

Supersedure of Queens Confined under Controlled Conditions

Table 3 presents a comparison of the attempted supersedure observed in the colonies to which 36 queens surviving 2 weeks of confinement were introduced and that observed in colonies of 12 queens installed on arrival from the South. These 48 queens were from one source. These data show that the confinement of the queens for 2 weeks did not increase the proportion of supersedure. The attempted supersedure of 22.9 percent for the 48 queens was comparatively high, considering the short period covered by the observations.

Table 3.--Comparison of attempted supersedure, after introduction to package bees, of queens confined 2 weeks before installation and queens installed on arrival from the South

Treatment	Number installed	Queens attempting supersedure	
		Number	Percent
Queens confined 2 weeks and then installed	36	8	22.2
Queens installed on arrival from the South	12	3	25.0
All queens installed	48	11	22.9

Survival of Queens Exposed to High Temperatures

Eight young laying queens from local colonies and eight young queens shipped from the South were provided with candy and water and confined for life in four cabinets operating at temperatures ranging from 98.3° to 111.4° F. Table 4 shows the longevity of these queens as well as that of their attendant bees under the various conditions. Some variations in relative humidity between the different cabinets were encountered, but, judging by the results obtained in other experiments, it is believed that these had little or no effect on the results.

Table 4.--Longevity of queens and attendants exposed to high temperatures (Food: candy and water)

Temperature, °F.	Relative humidity, percent	Queen number1/	Length of life in days		
			Queen	Attendants	
				Average	Maximum
111.4	22.0	M1	2/	2/	2/
		M2	2/	2/	2/
		E1	2/	2/	2/
		E2	2/	2/	2/
107.9	20.6	M3	4	3.1	4
		M4	3	3.7	5
		E3	3	3.5	5
		E4	2	3.3	4
103.7	17.6	M5	6	6.3	10
		M6	10	10.3	11
		E5	4	7.8	10
		E6	8	7.6	8
98.3	22.0	M7	61	33.6	39
		M8	56	24.5	29
		E7	49	27.0	42
		E8	26	18.1	27

1/ M = queen direct from mails; E = laying queen from local colony.

2/ All alive at end of 6 hours, dead at end of first day; exact time of death not determined.

The queens and attendants confined at 111.4° F. lived over 6 hours but less than 1 day. Length of life at the other temperatures was progressively greater as temperatures were reduced, the averages at 107.9°, 103.7°, and 98.3° being 3, 7, and 48 days, respectively. One queen (M7) lived alone 22 days in the mailing cage after her last attendant died; another (M8) lived alone 27 days. The continuous temperature of 98.3° was not particularly detrimental when water was available, but prolonged temperatures of 103.7° or higher materially shortened life. The length of life of the queens held at 103.7° with water in addition to candy, however, was greater than that of most of the queens held at temperatures below 100° without water in other experiments (table 1). It appears, then, that the chances of queens surviving the high temperatures frequently encountered during midsummer are materially increased by the use of water.

Longevity of Queens Confined in Mailing Cages with Attendants

Three queens were removed from experimental colonies in September 1937 and kept in cabinets operating at room temperature (about 70° F.) and about 25 percent relative humidity, with candy and water for food. Two of these queens lived over 60 days and the third more than 80 days.

Two queens removed from experimental colonies in February 1937 were kept in cabinets having a temperature of 85° F. and a relative humidity of 28.7 percent, with syrup (equal parts of cane sugar and water) and water as food. One queen died at the end of 33 days. The other was introduced to a colony early in April after having been confined 50 days. She maintained a good broodnest in the colony until the middle of September, when she was replaced. The long confinement apparently was not injurious. The longevity of these queens seems to show that the 3 percent of starch in the powdered sugar used in making the candy was not particularly harmful.

Longevity of Queens Confined in Mailing Cages without Attendants

Queens removed from experimental colonies in requeening operations were used to learn whether queens could survive as well without as with attendant bees. All queens were provided with candy and water and kept on a laboratory table for the duration of the experiment. The queens without attendants were placed in small one-hole mailing cages constructed for the purpose, and the other queens were placed in standard six-hole mailing cages. The queens with attendants were provided water in outside feeders, while each queen without attendants was given water in a small vial fitted into her cage. As the small vial did not seem to supply sufficient water, an outside feeder was also given to each queen without attendants after the first few days. Several queens without attendants died in 1 or 2 days, apparently because they were unable to get sufficient water from the small vials. Four queens in small cages without attendants, which did not show the effects of the shortage of water, lived alone 15, 17, 24, and 31 days, respectively. Five queens with attendant bees lived 12, 23, 41, 52, and 52 days, respectively. Another queen with attendants, alive at 36 days, was removed from the experiment and introduced to a colony. While more tests are necessary before conclusions should be drawn, it appears that queens with attendant bees have a somewhat better life expectancy than those without attendants.

The Use of Water Vials in Mailing Cages

Although the evidence obtained shows that water is highly beneficial to queens confined in mailing cages, some difficulties must be overcome before its use may become general for queens while in the mails. Several methods of supplying water during shipment have been tried, but none has been satisfactory. While some containers seem to function, others either fail to give sufficient water to the bees or allow the water to leak out. The water leaking from the containers frequently runs into the candy, and softens it so that the bees and queen become smeared with food and sometimes die. If, however, a reliable container is made available, it appears that by supplying water for the queens they may be shipped in better condition than is now the case without water.

The Use of Water for Queens Held in Storage

While it does not appear practical at present to use water in the shipping of queens through the mails, it is important to supply queens with water before shipment and between the time they are received and the time they are introduced to colonies. Sprinkling the cages with water is hardly an adequate method of supplying water. A container inverted over the screen of the cages so that the bees can obtain the water as they require it is the most satisfactory method tried. The small bottle with perforated screw cap shown in figure 1 makes the best feeder. The vial with the mouth covered by two thicknesses of cheesecloth held in place with cord or a rubber band serves the same purpose, but there is more danger of the water leaking into and softening the candy too much. The vial shown with grooves cut along one side of the cork stopper, which extends only to the mouth of the vial, is similar to that used in the early days. If a new cork is used, this method is satisfactory for a few days. Temperatures of 85° to 95° F. and relative humidities of 20 to 50 percent provide the queens being fed candy and water with suitable conditions. Extremely damp situations should be avoided.

Summary

The comparatively short life of queens in mailing cages indicates that the conditions ordinarily encountered or provided are not suitable. An investigation of the effects of temperature and relative humidity, as well as the influence of water and other foods on worker bees and queens in queen-mailing cages, was made to obtain information which might be used to improve conditions for shipping and holding queens. Some of the experiments consisted of exposing queens to controlled temperature and relative humidity conditions for from 3 to 17 days, and then introducing them to colonies for performance tests. In other experiments the longevity of worker bees and queens under continuous confinement was determined. The temperatures studied ranged from 68.0° to 111.4° F. The relative humidities ranged from 19 percent to nearly saturation.

The length of life of queens with attendants in mailing cages was comparatively short under all environmental conditions investigated when they were fed queen candy alone. When water was available to queens, the length of life was enormously increased under most environmental conditions tested. Only 10 percent of queens fed candy alone were able to live more than 5 days (temperatures, 85° to 99.5° F.; relative humidities, 19 to 66 percent), whereas all queens fed candy and water lived more than 5 days, and 93 percent of those held 2 weeks or more survived. No queen lived more than 10 days when fed only candy. Queens fed only candy lived an average of 3.2 days at the lower relative humidities (19 to 27 percent) and 4.7 days at the higher relative humidities (45 to 66 percent). Differences in relative humidity within these ranges had no apparent effect on queens provided with water confined as long as 17 days, but longevity studies with worker bees show that at low relative humidities they are able to adjust their water consumption to their requirements. Lower temperatures (68° to 75°) were more favorable than higher ones (98.6°) for worker bees fed candy, but the

higher ones were more favorable for those fed candy and water. No difference could be detected in the effect of temperatures between 85° and 99.5° on queens fed candy and water, but they were not able to live long at extremely high temperatures, even when water was provided. They lived only a few hours at 111.4°. The average lengths of life for queens fed candy and water at 107.9°, 103.7°, and 98.3° were 3, 7, and 48 days, respectively.

The maximum length of life obtained for queens in mailing cages was about 80 days. One queen confined to a mailing cage for 50 days, fed candy and water, maintained a good broodnest following the treatment. The confinement of queens under good conditions did not delay egg laying after introduction, or increase the proportion of supersedure attempted in the colonies to which they were introduced.

Candy containing 4 percent of pollen appeared to have no advantage over plain queen candy for queens in mailing cages. Candies prepared according to different formulas and lump sugar seemed to be equally valuable for worker bees when water was available. The hardness of the candy appeared to have no effect on the queens when they could obtain water.

Queens without attendant bees were able to live for extended periods in mailing cages when fed queen candy and water, but no records were obtained showing that they were able to live as long as with attendants. The maximum longevity obtained for such queens was 31 days. A comparable queen lived 52 days with attendants.

While supplying water to queens for use in shipment would appear to be materially beneficial, no satisfactory method of supplying water during shipment has been devised. Queens should be provided with water in a suitable container before shipment and between the time they are received from the mails and the time they are introduced to colonies. The place of storage should be warm and dry (temperature, 85° to 95° F.; relative humidity, 20 to 50 percent).

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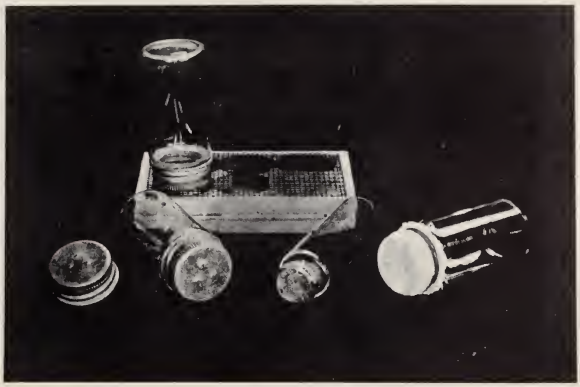

Figure 1.--Feeders used to supply water to queens in mailing cages. The screw-capped vial feeder, at the left and on the mailing cage, is the most satisfactory. The feeder in the center is closed by a grooved cork which fits flush with the mouth of the vial. The feeder at the right is covered with two thicknesses of cheesecloth held in place by a rubber band.